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# A STUDY ON UTILIZATION OF RECYCLED AGGREGATE AND POND ASH IN ROAD CONSTRUCTION

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## ABSTRACT

An excellent road network is an asset to any developing country and India in particular as it is one of the largest countries in the world and a perfect road network would complement its development. The road transport forms the arterial infrastructure to facilitate trading and transport of passengers and commodities. A flexible pavement which is the mostly used form of pavement has four component layers namely surface, subgrade, Sub-base and Base courses. Which are comprised of materials like natural aggregate, sand, Morrum etc, are proved to be costly affair in terms of construction as well as maintenance. For the purpose of easy maintenance and cheaper construction maintaining the same quality, materials obtained from demolishment activities and industrial wastes like recycled aggregate, pond ash, fly ash, bottom ash, GGBS can be used. For this study a combination of recycled concrete aggregate and pond ash mixed at different proportions has been studied for geotechnical characteristics such as compaction, gradation and strength characteristics. The pond ash has been used as a replacement to the material below the size 4.75mm . The results from this study are there by used in evaluating this combination of materials can be used in the pavement design and construction. Maximum CBR value was obtained at 30% dosage of pond ash is 55. From the experimental data, it is also seen that a dosage of 30-40% of pond ash to the recycled aggregate generates CBR values greater than 60% can be used for base course and greater than 30% has a sub base course materials as a replacement to natural aggregate and sand.

**KEYWORDS:** Pond Ash, Recycled Aggregate, CBR, Void Ratio, Sub-Base, Base-Course

## INTRODUCTION

Rapid population growth increases the demand for infrastructure facilities such as Roads, buildings, Bridges etc. This creates lot of structures and requirement of natural resources such as stones, sand, soils and other materials in their constructional activities. To reduce the impact on natural resources and their utilization in building industry, waste like recycled aggregate in various geotechnical applications especially in road construction is needed. Enormous quantities of demolished concrete wastes are available from construction industry and their disposal is a big task. Central pollution control board has estimated 12-15 million tons per annum. Instead of dumping on precious lands and utilization in pavement components is a promising area for their disposal. From the construction activity the amount of waste generated is increased day by day. Researchers like Sharma, P.C et.al(1998,1999), studied recycled aggregate concrete and its future perspective in construction activities, Singh, S.K et.al (1997,1998) studied recycled materials in Highways etc. Demolished concrete structures are proven to be a good source of construction material (Nik. D. Oikonomou 2004, Sumeda paranavithana, Abbas mohajerani (2006), Akash Rao et.al(2006), Kumar, P.R et.al (2007). Heeralal, M et.al(2009) studied the use of recycled aggregate in rigid pavements. Huang et.al (2005), Poon, C.S (2005), Kumar, P et.al( 2007,2008) studied that recycled aggregate is now being utilized as a Sub-base material for roads, non-structural concrete applications such as

kerbs, driveways, footpaths etc. Pond is an industrial waste obtained from thermal power plants by burning of coal. Its annual production coats hundred million tonns. Lot of research work has been under progress for the use of alternate material in road constructions. Pond ash is one such material which can be conveniently used in place of natural materials as well as it can be mixed conveniently with other road materials. Bera, A.K.et.al (2007) and Raju Sarkar et.al (2009) have studied the compaction and strength characteristics of pond ash. Amalendu Ghosh et. al., (2005), Venkatappa Rao .G et.al(2011) have studied the bearing capacity of geo-synthetic reinforced pond ash, Kumar, R et.al(2007) and Temel Yetimoglu et.al(2005) have studied the behavior of pond ash reinforced with randomly distributed fibers. Kolay, P.K et.al(2011) have used pond ash as stabilizer of peaty soil. Sridharan et.al(1996,1999) studied geotechnical characteristics of pond ash as a structural fill. The results showed that the use of pond ash in soils increases the peak friction angle, peak compressive strength, CBR value.

## MATERIALS AND THEIR CHARACTERISTICS

Pond ash was collected from local NTPC power plant, Parawada, Vishakhapatnam Andhra Pradesh. The collected pond ash was dried and subjected to various geo-technical characteristics such as gradation, compaction, seepage, strength etc and the test results are shown in table-1 and figure 1 and 2. Recycled aggregate was obtained from used concrete cubes, slabs and beams from the strength of materials laboratory college of engineering visakhapatnam, broken into individual sizes. After brushing the aggregate it was washed and dried. From the test results of pond ash the following identifications are made. The grain size distribution of pond ash shows that it consists 95% of sand size particles and 5% of silt size particles. Majority of Pond ash particles are under medium to fine sand range with rough surface texture. The gradation also shows it comes under Zone III. Based on BIS it is classified as poorly graded sand with non-plastic fines (SPN) with $C_u$ as 5.44 and $C_c$ as 0.84 and from the consistency data it is non-plastic and incompressible.Compaction characteristics of pond ash under modified compaction test has OMC of 14% and MDD as 1.4 g/cc. From the compaction curve it can be seen that pond ash attains higher densities with wider variation in moisture contents and increases the workability at higher moisture contents. Regarding strength characteristics it has an angle of shearing resistance (Ø) of 34 degrees under undrained condition and CBR of 5% and coefficient of permeability as 2.6 x $10^{-3}$ cm/sec.

**Table 1: Geotechnical Properties of Pond Ash**

| Property | Values |
|---|---|
| **Grain Size Distribution:** | |
| Gravel (%) | 0 |
| Sand (%) | 95 |
| Fines (%) | 05 |
| a. Silt(%) | 05 |
| b. Clay(%) | 0 |
| **Consistency:** | |
| Liquid Limit (%) | NP |
| Plastic Limit (%) | NP |
| I.S Classification | SPN |
| Specific gravity | 2.4 |
| Optimum moisture content (OMC) (%) | 14 |
| Maximum dry density (MDD) (g/cc) | 1.4 |
| Angle of shearing resistance(deg) | 34 |
| California bearing ratio (CBR) (%) (Soaked) | 5.0 |
| Coefficient of uniformity ($C_u$) | 5.44 |
| Coefficient of curvature ($C_c$) | 0.84 |
| Coefficient of permeability (k, cm/s) | $2.6x10^{-3}$ |

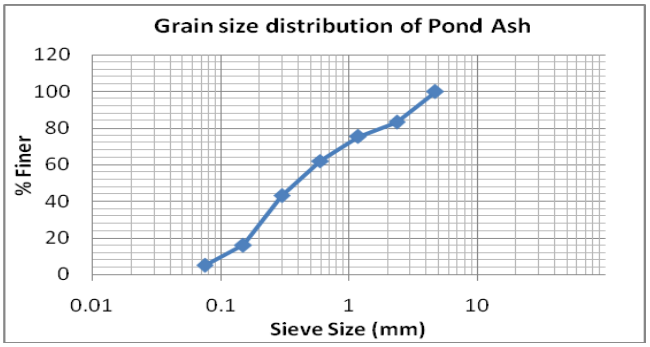


**Figure 1: Particle Size Distribution**

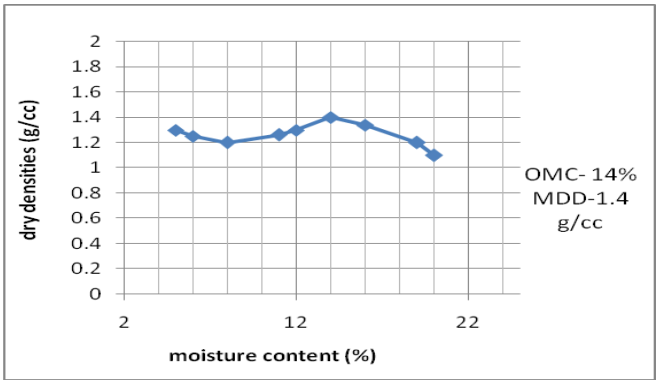


**Figure 2: Compaction Curve**

## METHODOLOGY

Recycled aggregate was obtained from used concrete cubes and slabs from the strength of materials laboratory and broken into individual sizes. After brushing the aggregate it was washed and dried. A set of sieves such as 53 mm, 26.5 mm, 9.5 mm etc. have identified for the gradation of recycled aggregate and 4.75mm, 2.36 mm, 0.425 mm, 0.075 mm sizes for pond ash were identified. Various percentages of Recycled aggregate was added to the pond ash as listed in table-2.

**Table 2**

| Sieve Sizes(Mm) | Recycled Aggregate Sizes | | | Pond Ash | Gradation Mixes |
|---|---|---|---|---|---|
| | 53-26.5mm | 26.5-9.5mm | 9.5-4.75mm | <4.75mm | |
| Percentage of Recycled aggregate & Pond Ash | 10 | 10 | 20 | 60 | G1 |
| | 10 | 20 | 20 | 50 | G2 |
| | 20 | 20 | 20 | 40 | G3 |
| | 20 | 20 | 30 | 30 | G4 |
| | 20 | 30 | 30 | 20 | G5 |
| | 30 | 30 | 30 | 10 | G6 |

Recycled aggregate mixed with pond ash was graded to various gradation mixes in accordance with MORTH specifications and named as G1, G2, G3, G4, G5, & G6 etc. These gradations mixes were subjected to various geotechnical characterizations such as compaction, strength (CBR), void ratio etc. The results are shown in table-3 and Figure 3,4,5,6.

## RESULTS AND DISCUSSIONS

### Compaction Characteristics

Modified proctor compaction tests were carried out on gradation mixes G1, G2, G3, G4, G5 and G6 as per IS 2720-Part 8: 1983 and the results are shown in table-3 and figure 3,4 and 5. From the test data, it is identified that maximum dry densities values are increased with the decrease in percentage of pond ash compared with respect to recycled

aggregate upto 30 to 40% i.e., from 2.06 g/cc to 2.17 g/cc and was decreased to 2.12 g/cc. whereas the Optimum Moisture Content values are decreased with increased in percentage of pond ash i.e., from 10.5% to 6.5%.

Attainment of high optimum Moisture contents are due to requirement of more water to coat pond ash particles at higher percentages (60-50%) as they depend on the physical characteristics of pond ash particles and at lower percentages of pond ash(<20%) low optimum moisture contents are due to availability of low percentages of pond ash particles for their requirement to coat these particles. Achievement of low maximum dry densities are due to the less effective replacement of formed voids resulting formation of honey combed structure. High maximum dry densities are due to filling of voids with small size aggregates and pond ash particles. At 30-40% of pond ash particles well graded formation ($C_u$ > 40 and $C_c$ >1) made the gradation mixes dense with less void ratios of 0.28 to 0.27.

**Table 3**

| Recycled Aggregate + Pond Ash | | | | | | |
|---|---|---|---|---|---|---|
| **Gradation Sieve Sizes** | **G1 (R40-P60%)** | **G2 (R50-P50%)** | **G3 (R60-P40%)** | **G4 (R70-P30%)** | **G5 (R80-P20%)** | **G6 (R90-P10%)** |
| 53.0 mm | 100 | 100 | 100 | 100 | 100 | 100 |
| 26.5 mm | 90 | 90 | 80 | 80 | 80 | 70 |
| 9.5 mm | 80 | 70 | 60 | 60 | 50 | 40 |
| 4.75mm | 60 | 50 | 40 | 30 | 20 | 10 |
| 2.36 mm | 60 | 42 | 34 | 25 | 17 | 8 |
| 0.425 mm | 33 | 28 | 22 | 17 | 11 | 5 |
| 0.075mm | 05 | 04 | 03 | 03 | 01 | 01 |
| **Compaction Characteristics** | | | | | | |
| OMC (%) | 10.5 | 10 | 9.3 | 8.3 | 7.8 | 6.5 |
| MDD(g/cc) | 2.05 | 2.09 | 2.13 | 2.17 | 2.14 | 2.12 |
| **Strength** | | | | | | |
| CBR Soaked | 18 | 32 | 50 | 62 | 46 | 38 |
| Void Ratio(e) | 0.3 | 0.29 | 0.286 | 0.27 | 0.3 | 0.325 |
| Specific Gravity ($G_c$) | 2.68 | 2.71 | 2.74 | 2.76 | 2.79 | 2.81 |
| Percentage voids | 23.5 | 22.9 | 22.2 | 21.3 | 23.2 | 24.5 |

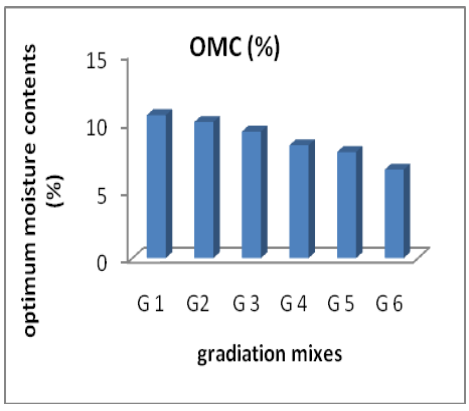


**Figure 3**

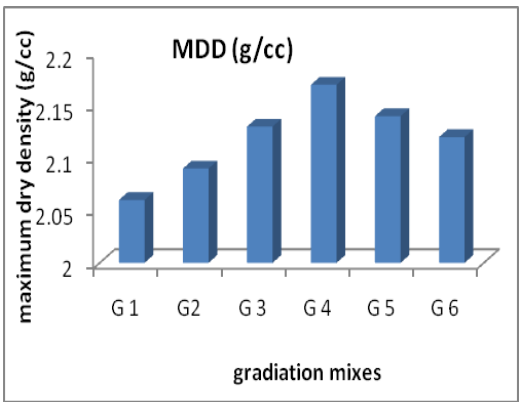


**Figure 4**

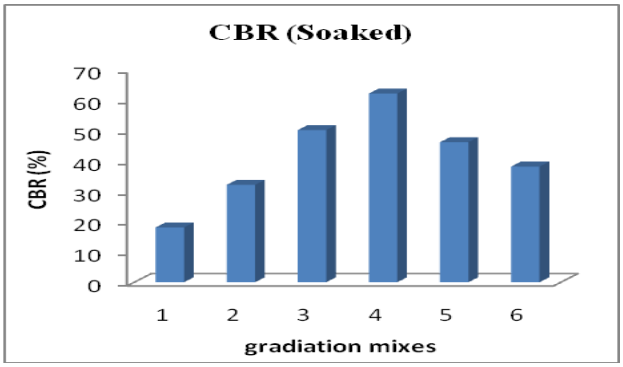


**Figure 5**

**Table 4**

| Gradation Mixes and Proportions | $C_u$ (Coeff. Uniformity) | $C_c$(Coeff. Curvature) |
|---|---|---|
| G1 (C40-P60) | 45.45 | 0.47 |
| G2 (C50-P50) | 43.75 | 0.72 |
| G3 (C60-P40) | 43.47 | 1.25 |
| G4 (C70-P30) | 41.67 | 1.89 |
| G5 (C80-P20) | 22.85 | 1.83 |
| G6 (C90-P10) | 6.4 | 1.03 |

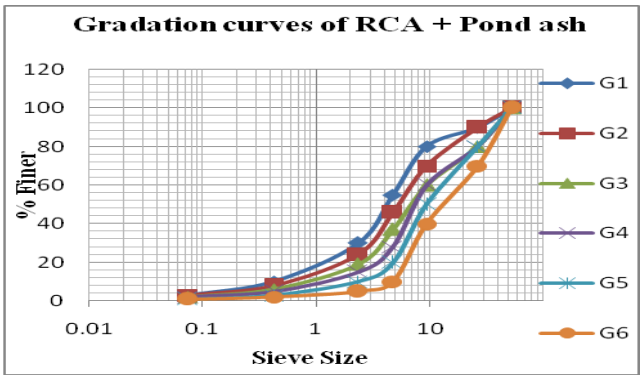


**Figure 6**

**California Bearing Ratio Test**

Dried Pond ash and Recycled aggregate materials at different gradation mixes are compacted in CBR moulds at their maximum dry densities and tested at 1.25 mm/min rate of strain as per IS: 2720- part 16 : 1987. From the test data of CBR, it is observed that maximum CBR values are obtained at 30-40% dosage are 50, 62. Attainment of higher values are due to formation of dense mixes offer more shear strength due to mobilization of frictional resistance under compression.

**Suitability of the Gradation Mixes for Sub-Base, Base Courses**

Comparing gradation mixes G1 to G6, with the gradation mixes of MORTH sub-base courses it is identified that at higher percentages of pond ash these mixes are nearing to Grade-II and Grade-III (Section 400-1) of close graded mixes and at lower percentages these are nearing to Grade-I. It can also see that the majority of the gradation mixes satisfying the Grades of coarse graded granular sub-base materials (Section 400-2). Hence, the gradation mixes of Pond Ash 30-40% with respect to Recycled Aggregate attaining CBR values greater than 50 can be recommended as base and Sub-base course materials and mixes attained CBR values greater than 30 can be used as Sub-base material.

## CONCLUSIONS

From the test results of the pond ash recycled aggregate mixes the following conclusions have drawn. Pond ash is mostly of medium to fine sand size of uniform gradation and with low specific gravity. Higher values of CBR of these mixes are attained in between 30-40% dosage of pond ash with dense packing can be used as Sub-base, Base course materials in Pavement constructions.

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